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Spatial and temporal patterns of an oribatid mite community in an evergreen-sclerophyllous formation (Hortiatis, Greece)

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With 6 figures

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1. Introduction

High species diversity is usually recorded in soil arthropod communities (ANDERSON, 1977) and oribatid mites are very often the numerically dominant group (WALLWORK, 1970; PETERSEN & LUXTON, 1982). Few things are known about the spatial and temporal organization of these communities in mediterranean type ecosystems, the physiognomy of which is characterized by a mosaic of randomly distributed microsites (PANTIS *et al.*, 1988, SGARDELIS, 1988) — partly resulting from overgrazing — and high species richness (DI CASTRI, 1973). Available information concerning soil microarthropods inhabiting Greek mediterranean type ecosystems is limited and most of it refers to phryganean ecosystems (SGARDELIS *et al.*, 1981; SGARDELIS & MAGARIS, 1983; SGARDELIS, 1988). Almost no attention has been drawn to soil microarthropods of evergreen formations. These systems are subject to intense grazing and consequently nutrient limited (unpublished data).

Soil arthropods are thought to be a major agent of nutrient recycling (e.g. MCBRAYER *et al.*, 1977). Thus the understanding of the spatial and temporal structure of the soil arthropod community in maquis is a prerequisite in order to assess their role in nutrient cycling. In this paper we provide information on the composition and spatial organization of the community of oribatid mites in a maquis system subject to overgrazing.

2. Site description

This study was carried out on a gentle, north facing hill slope (400 m a.s.l.) at Mt. Hortiatis about 20 km east of Thessaloniki. *Quercus coccifera* (L.) shrubs dominate by far the study area, whereas few *Juniperus oxycedrus* (L.) shrubs are also randomly dispersed. Shrub coverage may be as much as 60%, interspaced with *Poa bulbosa* (L.), *Anthoxanthum odoratum* (L.), *Dactylis glomerata* (L.), *Carex divulsa*, *Trifolium aureum*, *Lathyrus inermis* and other mainly grass species (ASIKIDIS, 1989). A narrow mossbank borders the *Q. coccifera* shrubs, while soil lichen patches are randomly dispersed within open sites.

Soil depth is about 0.8–1.0 m, while the depth of *Q. coccifera* litter and humus layers is 0–3 and 0–10 cm respectively, the humus layer consists of 10–14% clay, and 50–60% sand. Its nitrogen and organic matter content are about 0.12–0.14% and 8–12% respectively. The pH is 6.5.

Temperature at the soil/litter interface varied between 36 °C in June and –1.5 °C in February, whereas mean monthly temperature varied in the range from 25 °C to 2.5 °C. *Q. coccifera* litter water content varied from 10% in June to 61% in February and the corresponding values recorded for the humus layer were 15 and 54% respectively.

3. Materials and methods

Six microsite-types were distinguished inside the study area and sampled for soil microarthropods: Humus (HM) and litter (LT) layers of *Q. coccifera*, humus and litter layers of *J. oxycedrus* (JO), the zone of moss (MO), the lichen patches (LC) and the rhizospheres of grasses (GR).

From November 1985 to December 1986, at monthly intervals, five randomly distributed sample units were taken inside each microsite (30 units per sampling effort) with a steel cylinder (diameter = 5.4 cm). Animals were extracted from samples by means of a modified Berlese-Tullgren apparatus. The specimens were collected into a 5% salicylic acid solution in water to which 80% ethyl alcohol was added and counted at $\times 0.25$ under a stereomicroscope. Census data were analysed by using the Reciprocal Averaging (RA) ordination method (HILL, 1973).

4. Results

4.0. General

The Oribatidae was the most abundant microarthropod group samples at Hortiatis with a mean monthly density of 18,330 individuals m^{-2} (tab. 1). Oribatids were most evenly distributed

Table 1. Mean monthly population density of microarthropods sampled in 6 microsites at Mt. Hortiatis.

	Microsites						MEANS
	LT	HM	JO	MO	LC	GR	
Oribatids	4689	41983	19701	24202	14284	5167	18330
Prostigmatids	1518	1684	2422	6435	2485	1643	2698
Mesostigmatids	499	1341	530	1372	852	884	913
Collemboles	5728	19202	6476	15719	11872	8306	11217
Immatures/adults	0.26	0.16	0.26	0.16	0.19	0.44	0.25
Oribatids/prostigmatids	3.09	24.90	8.13	3.76	5.75	3.14	6.79
Acarines/collemboles	1.17	2.34	3.50	2.04	1.48	0.93	1.96

Note: The ratios immatures/adults, oribatids/prostigmatids and acarines/collemboles are also given. (LT and HM litter and humus layers of *O. coccifera*, JO organic layers of *J. oxycedrus*, MO mossbanks, LC lichen patches, GR grass).

among microsites and the highest mean monthly density was recorded in microsite HM. Mean monthly population density of prostigmatids was 2,698 individuals m^{-2} and most of them were sampled in microsite MO. Mesostigmatids appeared with lower mean monthly population density than the other two groups of acarines. The highest number for mesostigmatids was recorded in microsites MO and HM. Collembles dominated numerically in the open microsite GR and were most abundant in microsite HM, while their overall mean monthly population density was 11,217 individuals m^{-2} .

The value of the ratio immatures/adults for oribatids was 0.25. The value of the ratio oribatids/prostigmatids which is usually used as an index of biotope dryness (WALLWORK, 1967; DICASTRI & VITALI-DI CASTRI, 1981) ranged from 24.90 in microsite HM to 3.09 in microsite LT. Different values were determined for the ratio acarines/collemboles ranging from 3.5 in microsite JO to 0.93 in microsite GR.

Oribatids were numerous in the field mainly during autumn and winter, prostigmatids during the period from October to January, mesostigmatids during winter and spring and collembles in spring and autumn (fig. 1).

4.1. Spatial distribution pattern

Twenty eight species of oribatid mites were identified (tab. 2). All species were present in microsite MO, while in the other microsites some of them were missing. The values of Shannon species diversity did not differ considerably from the one microsite to the other and lay in the range of values reported by HÅGVAR & KJØNDAL (1981), SCHENKER (1984), STAMOU & SGARDELIS (1989) for oribatid communities in forest ecosystems and DOUCE & CROSSLEY (1977) for oribatids of a wet tundra.

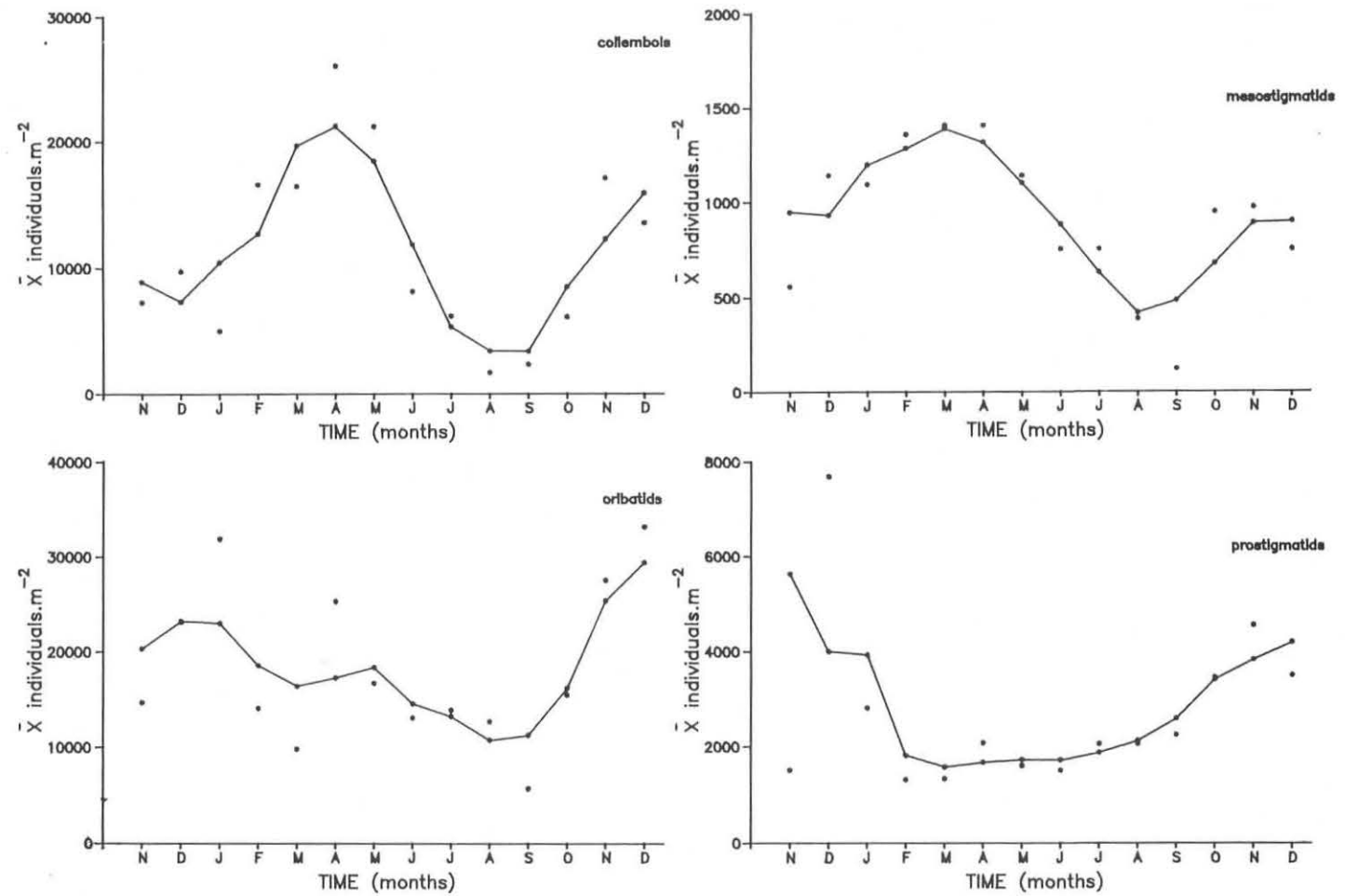


Fig. 1. Mean population density m⁻² of soil arthropod groups sampled from November 1985 to December 1986 at Mt. Hortatis. The scattered points correspond to original sensus data and the connected points correspond to smoothed data using the filter: $Y_t = \sum_{i=1}^3 X_i/3$.

Table 2. List and mean monthly density of oribatid species sampled in 6 microsites at Mt. Hortiatis.

<i>Sphaerochthonius splendidus</i> (BERLESE)	10604
<i>Camisia horrida</i> (HERMANN)	76
<i>Camisia spinifer</i> (C. L. KOCH)	48
<i>Liodes ionicus</i> (SELLNIK)	322
<i>Licnodamaeus pulcherrimus</i> (PAOLI)	2500
<i>Damaeus</i> sp.	19
<i>Metabelba pulverulenta</i> (C. L. KOCH)	69
<i>Microppia minus</i> (PAOLI)	1345
<i>Medioppia obsoleta</i> (PAOLI)	1819
<i>Multioppia</i> sp.	1055
<i>Quadroppia michaeli</i> (MAHUNKA)	367
<i>Hermanniella granulata</i> (NICOLET)	654
<i>Carabodes minusculus</i> (BERLESE)	1485
<i>Carabodes</i> sp.	152
<i>Tectocepheus velatus</i> (MICHAEL)	506
<i>Xenillus tegeocranus</i> (C. L. KOCH)	97
<i>Oribatula</i> sp.	187
<i>Protoribates capucinus</i> (BERLESE)	281
<i>Zygoribatula cognata</i> (OUDEMANS)	591
<i>Scheloribates</i> cf. <i>latipes</i> (C. L. KOCH)	814
<i>Scheloribates pallidulus</i> (C. L. KOCH)	68
<i>Zetorchestes micronychus</i> (BERLESE)	222
<i>Pilogalumna allifera</i> (OUDEMANS)	217
<i>Achipteris oudemansi</i> (VAN DER HAMMEN)	358
<i>Eupelops</i> cf. <i>halophilus</i> (PEREZ-INIGO)	161
<i>Peloptulus</i> cf. <i>phaeonotus</i> (C. L. KOCH)	99
<i>Rhysotritia ardua</i> (C. L. KOCH)	251
<i>Steganacarus pulcherrimus</i> (BERLESE)	76

To explore the distribution pattern of oribatids within the 6 microsites, the Reciprocal Averaging (RA) ordination method was used. The results are depicted in fig. 2. The first and the second axis account for 53 and 25% of the total data variability respectively. The spatial gradient represented by the first axis is about 2.4 half-changes (*sensu* HILL, 1973) which indicates highly heterogeneous spatial pattern.

It seems that the first axis of RA can be related to the depth of microsite organic layers (decreasing successively from microsite HM to microsite GR) and the associated physical properties of the habitats. Indeed, microsites HM, LT and JO are ordinated on the right half plane and microsite HM occupies the end point of the gradient, whereas open microsites are ordinated on the left half plane and microsite GR occupies the end point of the environmental gradient. Moreover, microsites are ordered on the first axis with respect to their vegetation structure resulting from overgrazing. Discontinuity in species composition of communities was detected between those in sheltered habitats and those in partly sheltered and open ones.

The species *Peloptulus* cf. *phaeonotus*, *Liodes ionicus*, *Eupelops* cf. *halophilus* and *Carabodes minusculus*, ordinated close to the left end point of the gradient, may be used as biological indices for overgrazing. *Achipteris oudemansi*, *Protoribates capucinus*, *Pilogalumna allifera* and *Xenillus tegeocranus* characterize the composition of the community in microsite LC and *Carabodes* sp. characterizes that in microsite MO. *Oribatula* sp. and *Tectocepheus velatus* share the mode of their spatial distribution between these sites. Community composition in microsite HM is determined by *Sphaerochthonius splendidus*, *Microppia minus* and juveniles of *Licnodamaeus pulcherrimus*. Adult *L. pulcherrimus* are ordinated close to microsite LT. This latter occupies the centre of the gradient. It indicates that the composition of the community in this site, characterized by the presence of *Zygoribatula micronychus* and *Hermanniella granulata*, can be considered as transient between those in covered and open sites. In intermediate positions between LT and HM are ordinated *Medioppia obsoleta*, *Scheloribates* cf. *latipes*, *L. pulcherrimus*,

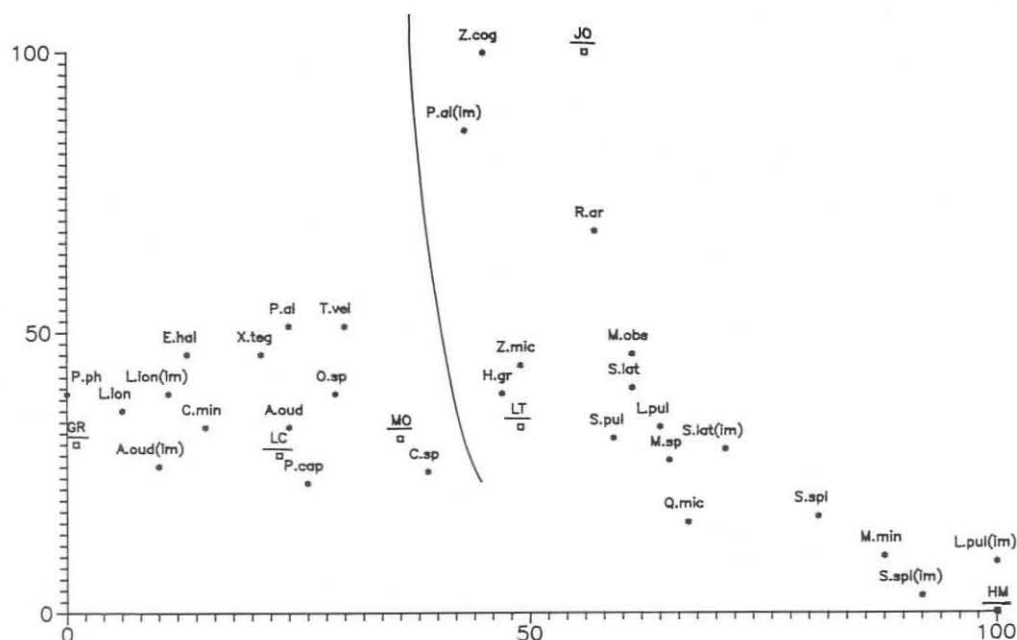


Fig. 2. Ordination of microsites and oribatid species on the plane of the two first axes of RA. (For microsite codes see text)

Multioppia sp. and *Quadroppia michaeli*. These species share the mode of their spatial distribution between these two microsites. Microsite JO occupies the upper end point of the second axis, while in relation to the first one it is ordinated between LT and HM. Thus, although the composition of the whole community in the former microsite could be compared to that in the two other sites, it is characterized by *Z. cognata* and immature *P. allifera* which were sampled in high numbers there.

4.2. Temporal pattern

The temporal distribution pattern of oribatids was also explored by using RA method. Data gathered in microsites LT, MO and LC were combined together, while data gathered in microsites HM, JO and GR were separately treated. The values of the parameters of RA are given in tab. 3

Table 3. The values of the parameters of RA ordination method used to explore temporal distribution patterns of oribatids sampled in different microsites.

Microsites	A	B	C
HM	31	21	1.16
JO	31	19	1.43
GR	21	19	1.65
LT, MO, LC	30	21	1.01

Note: A and B: contribution (%) of the first and second axis respectively to total data variability. C: length of the gradient in half-changes.

In figs. 3, 4, 5 and 6 is depicted the ordination on the plane of the two first axes of RA of oribatid species and monthly samples taken in the 6 microsites. Continuous succession pattern of

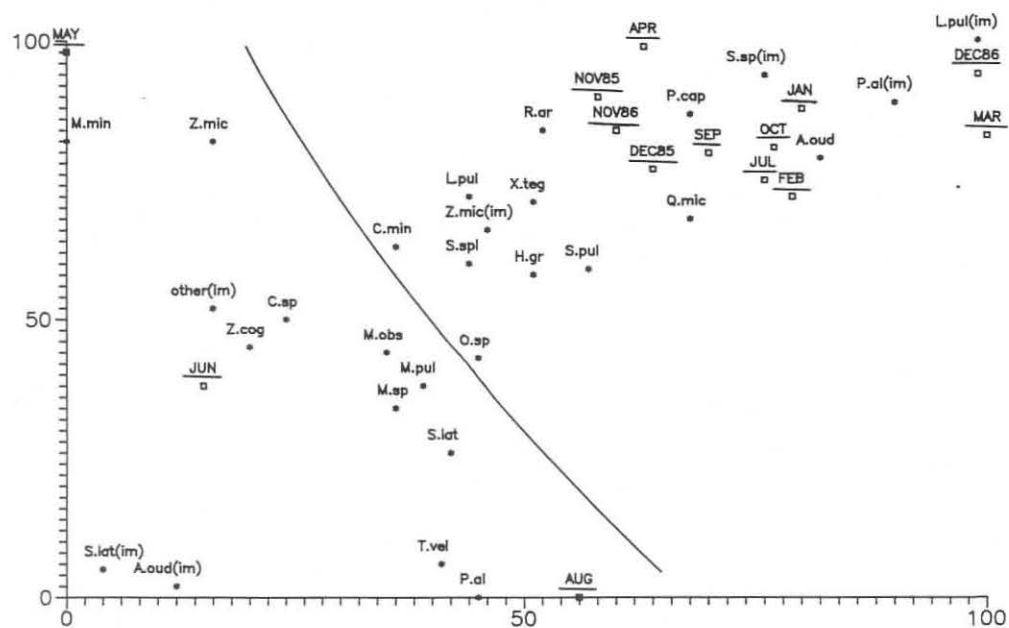


Fig. 3. Ordination of monthly samples and oribatid species sampled in microsite humus on the plane of the two first axes of RA.

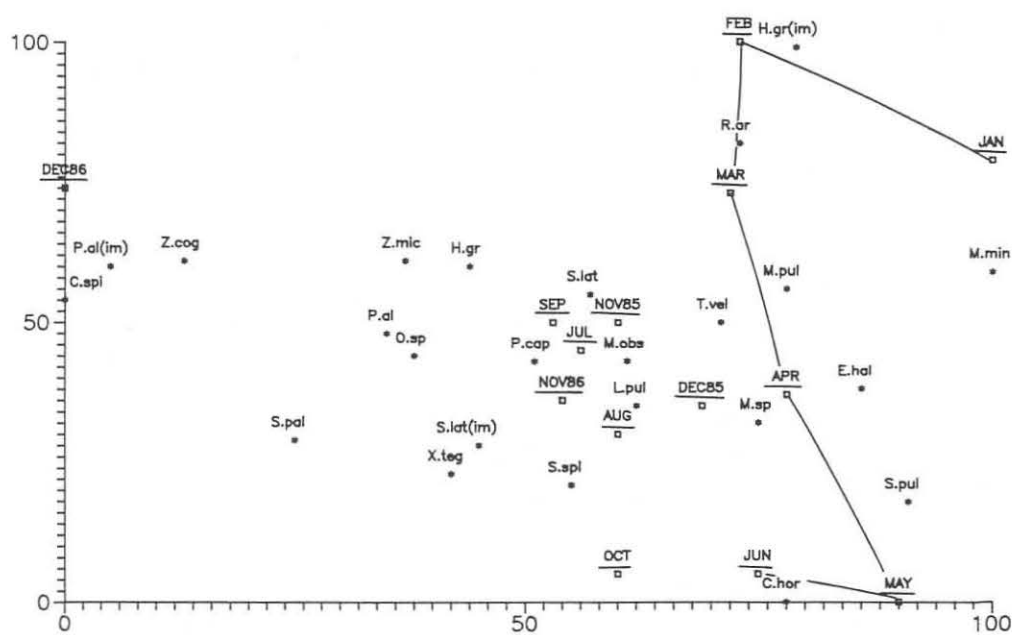


Fig. 4. Ordination of monthly samples and oribatid species sampled in the organic layers of *J. oxycedrus* shrubs on the two first axes of RA.

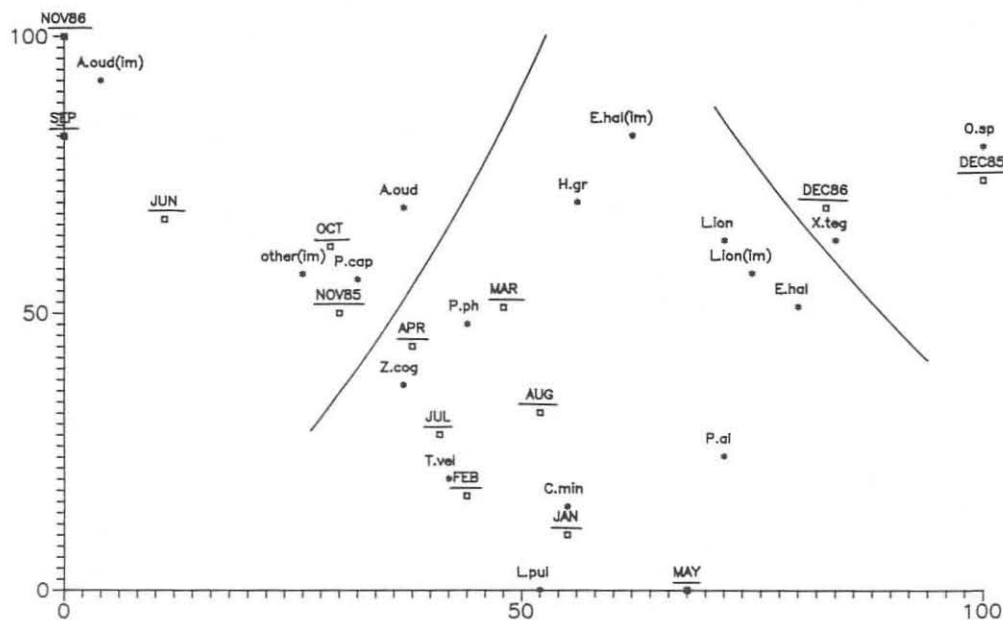


Fig. 5. Ordination of monthly samples and oribatid species sampled in the rhizospheres of grass species on the two first axes of RA.

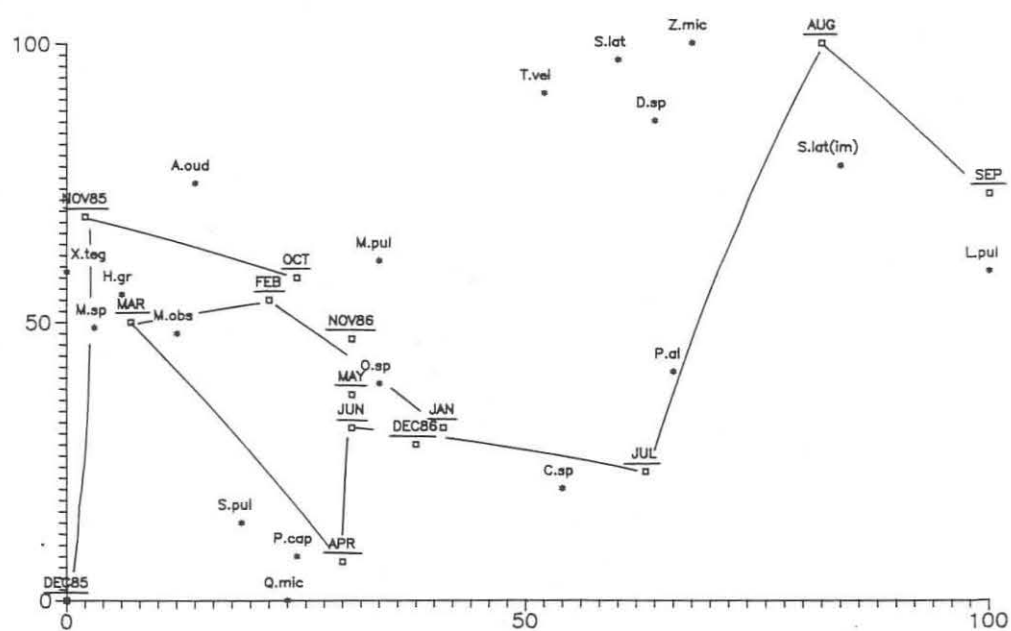


Fig. 6. Ordination of monthly samples and oribatid species sampled in litter, moss and lichen patch microsites on the two first axes of RA.

community can be observed only in microsites LT, MO and LC. Indeed, in these sites the composition of the community changes continuously from January to February and then to March since a continuous line can be drawn through these monthly samples. Continuous changes, although in the opposite direction, occurred also from March to September. Yet, continuous changes in the community can be observed from October to December. Also in microsite JO can be observed continuous pattern from January to June with respect to the second axis of RA. This pattern is characterized by succession in dominance of oribatid species. Indeed, *M. mihus*, immature *H. granulata*, *Rhysotritia ardua*, *Multioppia* sp., *S. pulcherrimus*, and *Camisia horrida* displayed their mode of distribution during January, February, March, April, May and June successively.

In microsite HM discontinuities in community composition occur during the transition from spring to summer and from summer to autumn. Most species are ordinated towards the centre of the plane indicating constancy in numbers the year round. Discontinuities in the composition of the community in microsite JO occur during the transition from June to July and again from December to January. In any case, most species are ordinated towards the centre of the plane indicating a more or less even distribution of numbers the year round. A temporal pattern may be described and the composition of the community changes drastically during the transition from summer to autumn and again from autumn to winter in microsite GR. In microsites LT, MO, and LC discontinuities in the temporal succession pattern are recorded during the transition from June to July and again from September to October and from December 1985 to January.

In general, monthly samples taken from November to March are ordinated close to the one end point of the plane (either in relation to the first or the second axis of RA) and close to the other end point are ordinated monthly samples made from May to September. The immatures of *P. allifera*, *L. pulcherrimus* and *H. granulata*, as well as adults *X. tegeocranus*, *Oribatula* sp., *R. ardua* and *Multioppia* sp. have the mode of their temporal distribution during the first period. The immatures of *S. cf. latipes* and *A. oudemansi*, as well as the adults of *M. minus*, *Z. micronychus*, *T. velatus*, *P. allifera*, *L. pulcherrimus* and *C. horrida* have the mode of their distribution during May–September. Most immatures are ordinated close to the end points of the axes, a fact indicating that they develop over short time periods into adults.

5. Discussion

According to DI CASTRI (1973), population densities of soil animals inhabiting mediterranean type ecosystems lie within the range of densities from that recorded in dry savannahs to those recorded in temperate ecosystems. A similar observation was also reported by SGARDELIS *et al.* (1981). At Hortiatitis, the mean monthly population density recorded for acarines and collemboles is comparable with values reported for diverse ecosystem types and occupy the centre of PETERSEN & LUXTON's (1982) histogram. This can be attributed to the fact that the determination of the mean monthly densities were based on census data from six different microsites representing a wide spectrum of ecosystem types. Indeed, mean monthly density recorded in microsites GR and LT is comparable with those reported for arid ecosystems, whereas mean monthly population density recorded in microsite HM is comparable with those reported for temperate forests. The above comparisons could be illustrated by inspecting the ratios oribatids/prostigmatids and acarines/collemboles. The consideration of these ratios provides similar conclusions, i.e. (following DI CASTRI, 1973), the 6 microsites sampled at Hortiatitis can be ranked from the hygric to the semi-arid end of the vegetation spectrum.

A high number of acarines was recorded in winter and collemboles were abundant in spring and autumn. This is in accordance with observations reported for other formations of the temperate zone (HARLØV, 1960; ALICATA *et al.*, 1973; SGARDELIS & MARGARIS, 1983). WALLWORK (1972) suggested that in general soil microarthropods are numerous during spring and autumn. At Mt Hortiatitis this pattern is displayed only by collemboles, the majority of which are mesophilous species avoiding dry and wet soils (PETERSEN & LUXTON, 1982).

The distribution of oribatid populations within the six microsites is controlled by habitat properties. Analogous conclusions have been suggested by AOKI (1967), SCHENKER (1984),

KANEKO (1985) and STAMOU & SGARDELIS (1989). USHER (1975), suggested that 3 factor-types underlie the spatial distribution of soil animals. Factors linked to intraspecific relationships, and those related to the distribution of egg laying sites are associated with small scale spatial patterns, while vectorial factors related to the abiotic environmental variables cause large scale patterns, like the one explored here and this has been demonstrated by many authors (e.g. GJELSTRUP, 1979; GARAY *et al.*, 1980; SZLAVECZ, 1985; BELLIDO & CANCELA DA FONSECA, 1988). Environmental variables are not independent of each other and the composition of the community is determined by their combined effect. The adaptations of organisms refer to their anatomical traits (TARBA & SEMENOVA, 1976), to their food preferences (LEBRUN, 1971; LUXTON, 1972), to their reaction to temperature fluctuations (STAMOU, 1981), photoperiodism (LEBRUN, 1970) etc. Thus, species with small size and soft exoskeleton, microphytophages, hygrophilous species, stenotherms and scotophilous species are ordinated closely to the right end of the first axis of RA. In contrast, species with large size and hard exoskeleton, macrophages, species able to withstand drought and eurytherms are ordinated close to the left end point of the environmental gradient. Few species sampled at Hortiatis display general habitat selection; most of them are closely related to certain microsites. In any case, the spatial organization of the oribatid community parallels that of vegetation induced by overgrazing.

Regarding the temporal organization of the community, the RA method revealed a general temporal pattern involving fundamental changes in the composition of the community mainly during the transition from spring to summer and again from summer to autumn and from autumn to winter. These discontinuities can be linked to the transition from the wet to the dry season, again from the dry to the wet season and from the mild autumnal temperatures to the low temperatures occurring in winter. Most authors suggest that temporal distribution of oribatid populations is controlled by changes in environmental variables. Thus, in temperate forests either rainfall and litterfall (LUXTON, 1981) or temperature (USHER, 1975; SOLHOY, 1975), in semi arid systems rainfall (GOFFINET, 1973; IZZARA, 1977) and in phryganic systems the onset of microbial activity (SGARDELIS, 1988) are factors causing numerical changes in oribatid populations. At Hortiatis, the oribatid community displayed plasticity against environmental hazards and the discontinuities in its composition were related to regular oscillations of the mediterranean climate. Although no continuous changes in community composition were generally recorded the unpredictable oscillations in the community structure lie inside the range of seasonal changes. SGARDELIS (1988) studying the effect of a natural fire on the composition of the soil microarthropod community in a phryganic ecosystem showed that changes in community composition caused by environmental hazards lie within the range of seasonal changes imposed by the regular and predictable temporal fluctuations of the mediterranean climate. It seems likely that this holds also for the evergreen mediterranean formation at Hortiatis.

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The spatial and temporal components of the oribatid mite community in a mediterranean-type maquis ecosystem were studied. Six microsites representing the vegetation degradation gradient resulting from overgrazing were sampled for soil microarthropods. Faunal composition varied among microsites and can be compared with those recorded in the range from the semi-arid up to the hygric regions. The organisation of the community changes evenly from one site to the other in conjunction with changing habitat properties. The community succession pattern paralleled that of vegetation. The structure of the oribatid community remained rather stable throughout the year in protected sites. It displayed a cyclic pattern in response to the seasonal fluctuations of the mediterranean climate in partly sheltered sites. In the open site the irregular changes in community structure caused by environmental hazards lie within the range of the seasonal ones.

Key words: Mediterranean type ecosystems, soil microarthropods, oribatid mites, community structure, spatial patterns, temporal patterns

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